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Enhanced Animal Productivity and Health with Improved Manure Management in 2nd Generation Environmentally Superior Technology in North Carolina: II. Air Quality

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Abstract. *The aim of this study was to evaluate the effects of improved manure management on air quality and the beneficial effect of a cleaner environment on animal productivity and health using a second generation of Environmentally Superior Technology. The second generation system combines solid-liquid separation, biological ammonia treatment, and phosphorus removal, and it produces a deodorized and disinfected liquid effluent. The system was installed full-scale in a 5,600-head finishing swine operation in North Carolina and demonstrated for one year under steady-state conditions. Ammonia concentration in air of the barns was reduced due to the recycle of cleaner, sanitized water to refill barn pits. Compared to the lagoon system, the new system lowered ammonia concentrations in the air inside the barns by an average of 40.3% at the operator nose level, 44.5% at the pig nose level, and 58.1% in the manure pit atmosphere below the slotted floor. Pronounced differences were also found in the quality of air blown outside the barns by ventilation fans; the average ammonia concentration reduction in the exhaust air was 75.1% with the use of the new treatment system. The improved housing environment enhanced animal health and productivity: mortality decreased 57%; daily weight gain increased 11%; and feed conversion improved 5.4% compared to the traditional lagoon management. These improvements resulted in substantial economic benefits to the farmer. These results overall show that cleaner alternative technologies can have significant and positive impacts on livestock production and the environment.*

Keywords. *Animal waste treatment, Swine manure, Ammonia volatilization, Animal housing.*

Introduction

A new wastewater treatment system was developed to replace the anaerobic swine lagoon technology commonly used in the USA to treat swine waste (Vanotti et al., 2007a). The system met the criteria of an environmentally superior technology (EST) as determined by an agreement between government and swine industry to find technologies that could replace the lagoon system (Williams, 2006). The environmental performance standards of an EST are the following: (1) eliminate the discharge of animal waste to surface waters and groundwater through direct discharge, seepage, or runoff; (2) substantially eliminate atmospheric emissions of ammonia; (3) substantially eliminate the emission of odor that is detectable beyond the boundaries of the swine farm; (4) substantially eliminate the release of disease-transmitting vectors and airborne pathogens; and (5) substantially eliminate nutrient and heavy metal contamination of soil and groundwater.

The first generation technology was demonstrated full-scale on Goshen Ridge farm, a 4,400-head finishing farm in Duplin County, NC. This first generation technology met the environmental performance criteria of an EST (Williams, 2006). It was determined as an unconditional EST for new farms which are permitted and constructed for the first time after March 2005 and for expansion of existing swine farms (Williams, 2006). Recommendations were also made to evaluate an improved, redesigned second generation version of the wastewater treatment system. The new system design is based on experiences gained during first generation demonstration and incorporates new science (Vanotti et al., 2007b). It is intended to significantly lower capital, maintenance and operating cost of the system without lagoon and also improve system reliability and simplicity.

Substantial animal production advantages can be realized by improvements in manure management. Barker (1996) documented with many examples the direct linkage between improved manure management and improved air quality in the barn - especially lower ammonia concentrations - and their combined effect on animal productivity and health. Indicators of better productivity and health were healthier pigs, reduced mortality, increased daily gain, improved feed conversion, and substantial economic benefits to the producer. The objective of this study was to evaluate the effects of improved manure management on air quality and the beneficial effect of a cleaner environment on animal productivity and health. The study was done at full-scale on a 5,600-swine finishing farm where the manure management system was converted from anaerobic lagoon to a new EST wastewater treatment system. Research results on water quality are reported by Vanotti and Szogi (2008; this symposium proceedings).

Materials and Methods

New Wastewater Treatment System

The on-farm system uses solid-liquid separation, biological nitrogen removal, and disinfection and phosphorus removal unit processes linked together into a practical system for livestock operations (Figure 1). The system greatly increases the efficiency of solid-liquid separation with flocculation of the suspended solids using polymer. Nitrogen management to eliminate ammonia emissions is accomplished by passing the liquid through a biological module containing nitrification and denitrification bacteria adapted to high-ammonia wastewater. Subsequent alkaline treatment of the liquid in a phosphorus removal module precipitates phosphate and kills pathogens. The phosphorus precipitate is simultaneously separated with the manure. The system recycles clean water to flush the barns. The treated water is stored in the former lagoon and used for crop irrigation. The solids are removed from the farm and used for the manufacture of value-added products and energy production. Detailed description of the new system is provided in Vanotti and Szogi (2007).

Swine Farm Characteristics

The full-scale demonstration facility was installed on B&B Tyndall farm in Sampson Co., near Clinton NC, and evaluated intensively under steady-state conditions. The farm contained seven swine barns and two traditional anaerobic lagoons of equal area (0.58 ha each) for treatment and storage of the manure (Figure 1). Manure was collected under the barns using slotted floors and a pit-recharge system typical of many swine farms in North Carolina and treated and stored in the anaerobic lagoons. Under this traditional management, lagoon liquid was recycled into the barns to recharge the pits under the slotted floor and facilitate flushing of the newly accumulated manure.

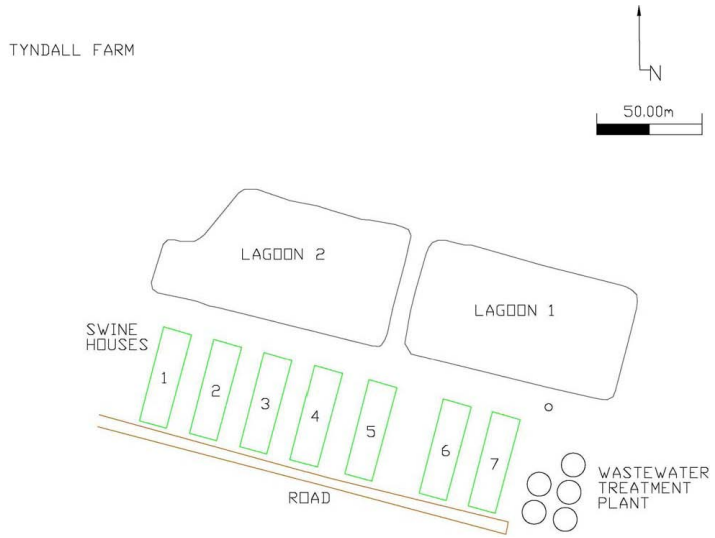

Figure 1. Wastewater treatment system retrofitted into a 5600-head swine finishing farm.

Air Quality Measurements

Ammonia concentrations in the air inside the barns were measured using a Dräger CMS Analyzer and Remote System (Dräger Safety AG & Co. KGaA, Luebeck, Germany). The accuracy of the method is ± 4-7%. The analyzer uses capillary chips, a mass flow controller and pump system that pulls the same mass of air through the capillary, and a photo-optical controller for analyzing the chemical reaction. All measurements were started with capillary chips having a 0.20 – 5.0 ppm ammonia scale. When the ammonia concentration was > 5.0 ppm, the measurement was repeated on the spot using chips with a 2.0 – 50.0 ppm range. Thus, the detection limit of the procedure was 0.20 ppm ammonia. Monthly measurements were done in the same two barns (barns # 2 and 6) at the following three points inside the barn: 5 ft (1.5 m) height (operator nose), 1 ft (0.3 m) height (pig nose), and 6 in (0.15 m) below the concrete slotted floor (inside the manure pit atmosphere). A telescopic probe and remote system (Dräger CMS) were added to the analyzer

to measure ammonia in the pit atmosphere. Ammonia concentrations were also measured in the air blown out by the large exhaust fans that provided ventilation to the buildings. Measurements were done during a 4-month period in 2006 using the lagoon system and repeated in 2007 using the new treatment system.

Air ammonia concentrations obtained with the Dräger CMS Analyzer were compared with those obtained with an open-path diode laser absorption spectroscopy system (OP-TDLAS, gas Finder 2.0, Boreal Laser Inc., Spruce Grove, Canada). Measurements were done at Tyndall farm simultaneously at the following points: inside two barns (2 and 6) at 5 ft (1.5 m) height, at the exhaust fans of the same barns, and at an adjacent field approximately 150 m from the barns as a background measurement. Results showed a good agreement between measurement methods ($y = 0.97x + 0.47$, $R^2 = 0.98$). However, the CMS analyzer was used in this evaluation because measurements were easier and faster to perform, and it allowed for measurements in the pit atmosphere below the slatted floor that were not possible with the laser system.

Results and Discussion

Reduction of Ammonia in the Barns

Ammonia concentration in the air inside the barns was measured during traditional lagoon treatment in 2006 and again with the new treatment system in 2007 in the same barns (barns # 2 and 6) during the same time of the year (May-September). Each of the four-month measurement periods included pig sizes representative of a full production cycle; the average pig weight per barn was 51,363 kg during 2006 measurements and 51,276 kg during 2007 measurements.

Results of the air measurements showed a vertical gradient of ammonia inside the barns with higher concentrations close to the liquid manure in the pit (Table 1). However, the new system had significantly lower ammonia concentrations in the air than the lagoon management system at all depths, and the differences between management systems were more pronounced at the lower depths. Compared to the lagoon system, the new system lowered ammonia concentrations in the air inside the barns by an average of 40.3% at the operator nose level (from 3.05 to 1.82 ppm), 44.5% at the pig nose level (from 3.73 to 2.07 ppm), and 58.1% in the manure pit atmosphere below the slotted floor (from 12.09 to 5.06 ppm).

Table 1. Ammonia concentrations in the air inside the swine barns and in the ventilation air exiting barns.

Manure Management System	Average total pig weight/barn during measurement period	Ammonia Concentration in Air Inside the Barns[a]			Ammonia in Air Outside the Barns
		Operator Nose Level	Pig Nose Level	Manure Pit Below Floor	Ventilation Fans
	kg × 1000	---------- ppm NH_3 ----------			
Lagoon System May – Sept 2006	51.4 ± 23.6	3.05 ± 2.18	3.73 ± 2.18	12.09 ± 9.99	11.30 ± 3.68
New System May – Sept 2007	51.2 ± 25.0	1.82 ± 0.99	2.07 ± 1.21	5.06 ± 4.50	2.81 ± 1.07
% Change[b]	-0.2% NS	-40%*	-45%*	-58%*	-75%***

[a] Ammonia values are averages ± standard deviation of monthly measurements in barns #2 and 6.
[b] NS = Non significant; * and *** significant at 0.05 and 0.001 probability level, respectively.

Pronounced differences were also found in the quality of the air blown to the outside by the barn's ventilation fans; the average ammonia concentration reduction in the exhaust air was 75.1% with the use of the new treatment system (from 11.3 to 2.81 ppm) (Figure 2).

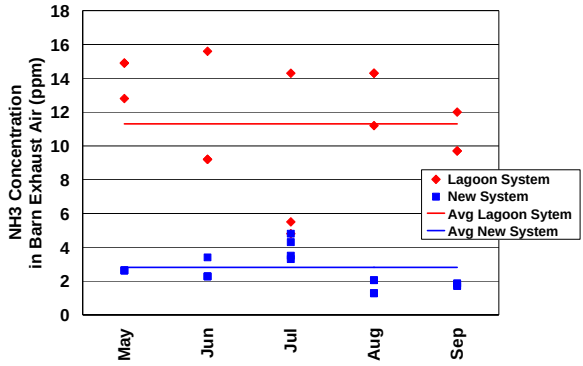

Figure 2. Ammonia concentrations in fan exhaust air with the traditional lagoon system (2006 measurements) and the new treatment system (2007 measurements).

Animal Productivity and Health Improvement

The reuse of cleaner, sanitized water to refill barn pits reduced ammonia concentration in the air and improved the growing environment. About one third of the treated water was reused on the farm to flush the pits under the barns (Vanotti and Szogi, 2008). It replaced the dirtier lagoon liquid charged with ammonia used for the same task under the traditional lagoon management. As a result, animal health and productivity were enhanced (Table 3). These data show that, compared to lagoon management, significantly fewer pigs died as a result of the cleaner environment (mortality decreased 57%). In addition, the rate of feed conversion into meat improved 5.4%. The pigs also grew faster with the cleaner environment. The average daily weight gain (kg/pig/day) increased 11%. Results obtained in this demonstration project are consistent with the observations of Barker (1996) on the substantial animal production advantages that can be realized by improvements in manure management in swine production buildings.

Table 3. Improvement of animal productivity and health indicators obtained with the new waste treatment system compared with the previous lagoon system. Data are means ± s.e. of production records in seven barns (n=7).

Indicator	Old lagoon system Oct. 2005 - Dec. 2006	New system Dec. 2006 – May 2007	Percent Change[a]
Mortality (%)	7.06 ± 0.96	3.06 ± 0.80	- 56.7%
Daily Gain (kg/pig/day) [b]	1.553 ± 0.020	1.718 ± 0.02	+ 10.5%
Feed Conversion (kg feed/kg meat) [c]	2.61 ± 0.04	2.47 ± 0.03	-5.4%
Condemnation (%) [d]	0.21 ± 0.13	0.13 ± 0.07	-38.1%

[a] % Change compares performance obtained with the new system with average performance obtained in three previous cycles using the lagoon system.
[b] Daily gain = Finished weight minus start weight divided by number of days on feed.
[c] Actual feed conversion after condemnation.
[d] Entire hogs that did not pass inspection.

Conclusion

The aim of this study was to evaluate the effects of improved manure management on air quality and the beneficial effect of a cleaner environment on animal productivity and health. The study was done at full-scale on a 5,600-swine finishing farm where the manure management system was converted from anaerobic lagoon to a new EST wastewater treatment system. Ammonia concentration in air of the barns was reduced due to the recycle of cleaner, sanitized water to refill barn pits. Compared to the lagoon system, the new system lowered ammonia concentrations in the air inside the barns by an average of 40.3% at the operator nose level, 44.5% at the pig nose level, and 58.1% in the manure pit atmosphere below the slotted floor. Pronounced differences were also found in the quality of the air blown to outside the barn by ventilation fans; the average ammonia concentration reduction in the exhaust air was 75.1% with the use of the new treatment system. Animal health and productivity of the animals were enhanced; mortality decreased 57%, daily weight gain increased 11%, and feed conversion improved 5.4% compared to the traditional lagoon management. These results overall show that cleaner alternative technologies can have significant positive impacts on livestock production and the environment.

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